Real–Time Hatching

Emil Praun — Princeton University

Hugues Hoppe — Microsoft Research

Matthew Webb — Princeton University

Adam Finkelstein — Princeton University

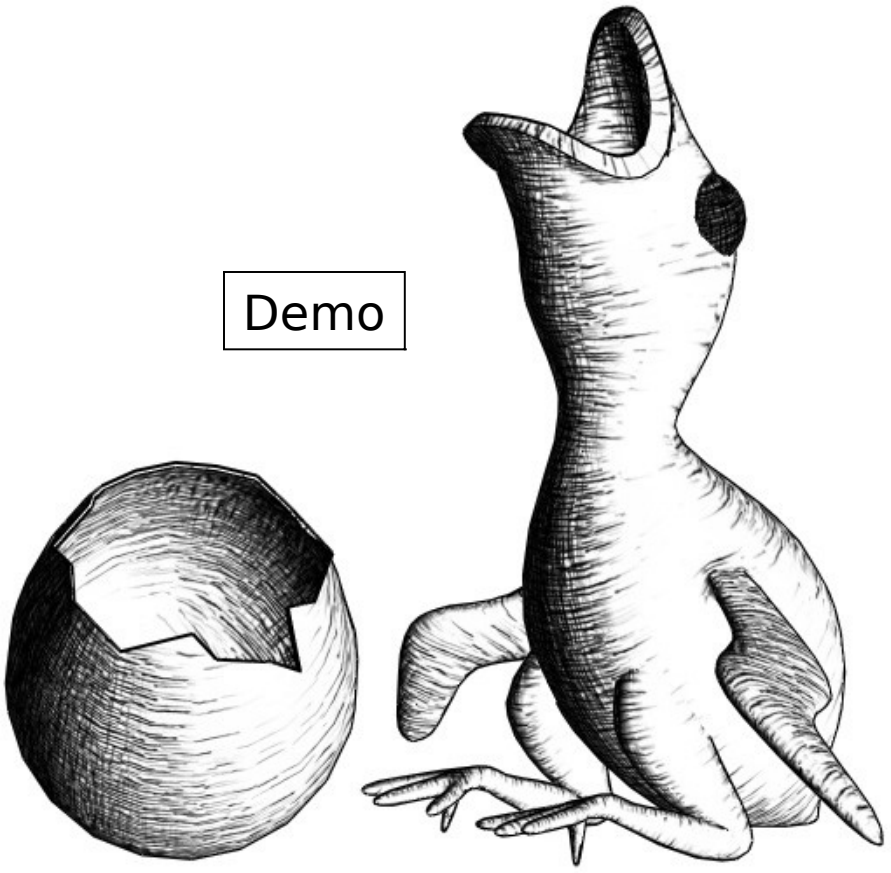
Goal

Stroke-based rendering of 3D models

Strokes convey:

- tone
- material
- shape

Demo



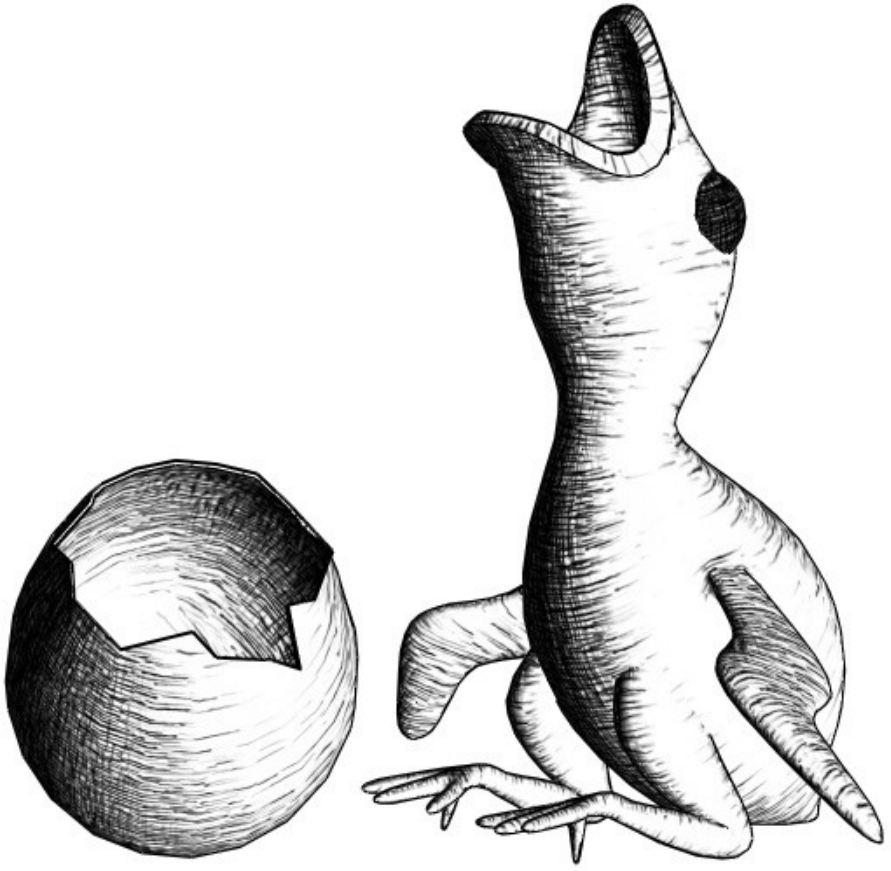
Challenges

Interactive camera and lighting control

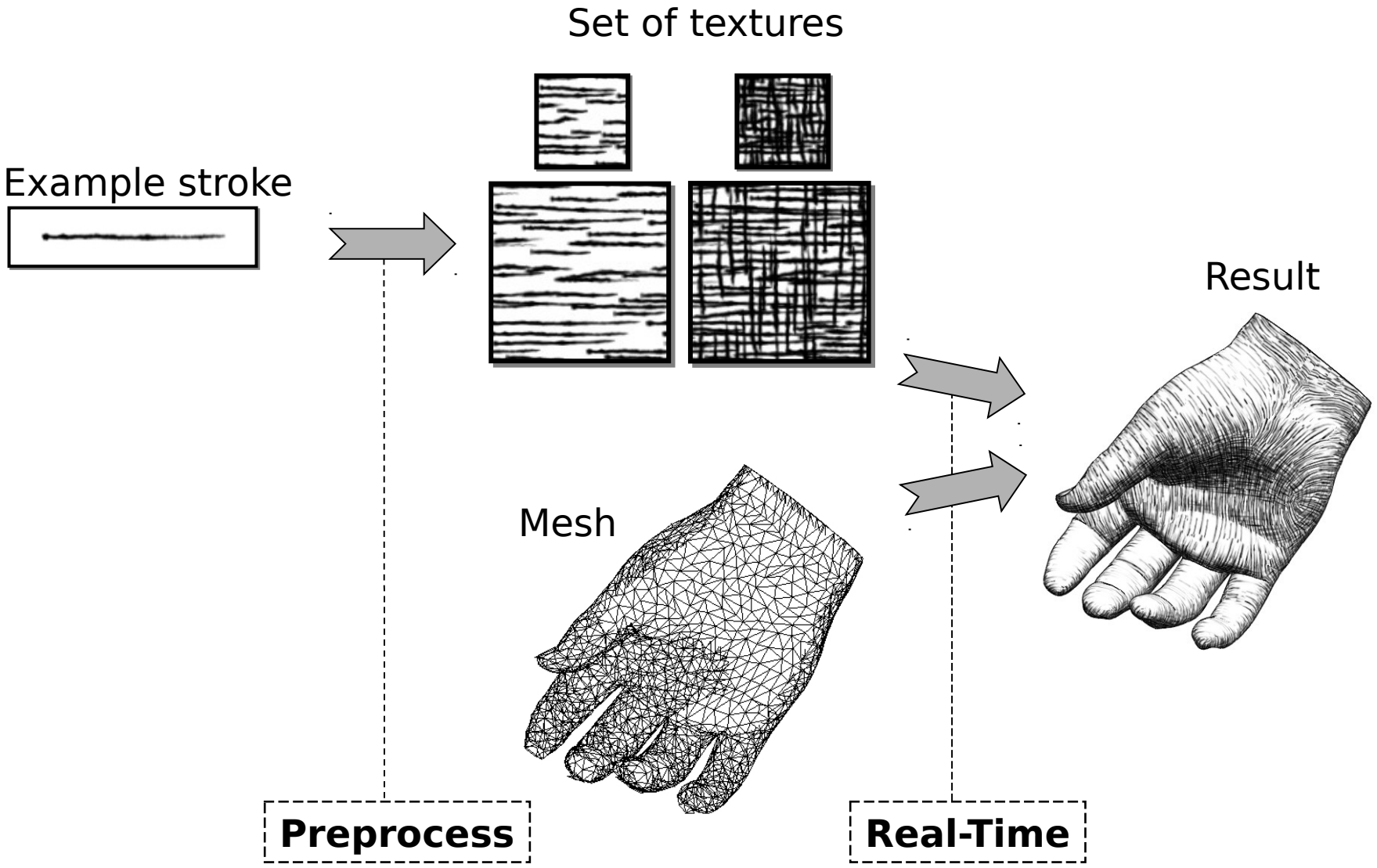
Temporal (frame to frame) coherence

Spatial continuity

Artistic freedom



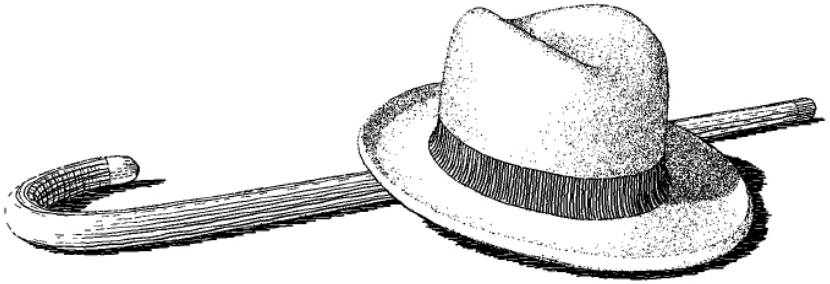
Approach


Set of textures
Example stroke
Result
Mesh
Preprocess
Real-Time

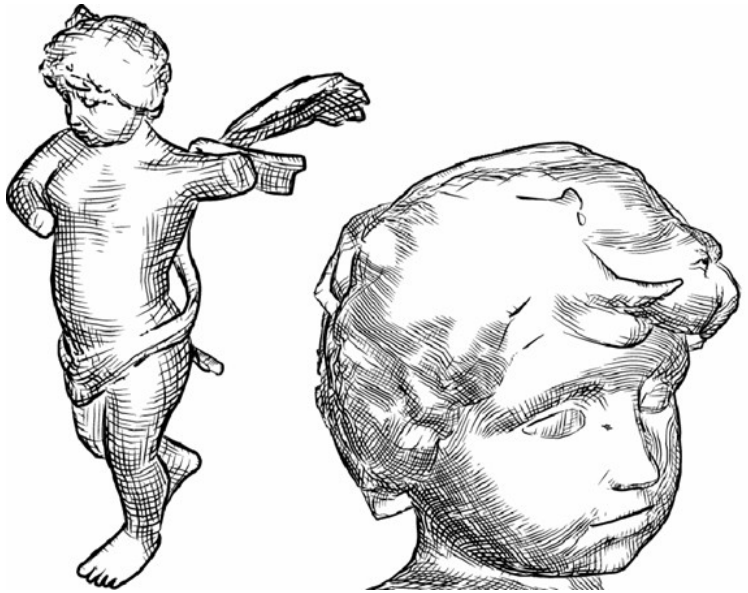
Previous Work

Off-line

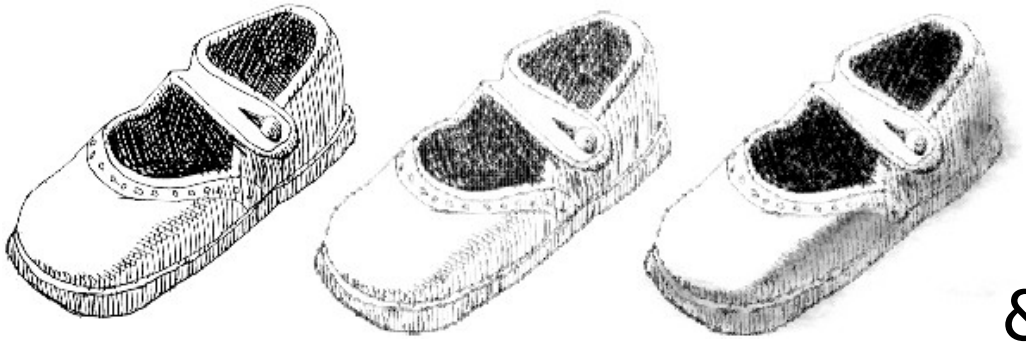
~~Real-Time~~ Hatching



[Winkenbach *et al.* ’94, ’96]



[Hertzmann *et al.* 2000]



[Sousa *et al.* ’00]

& many others …

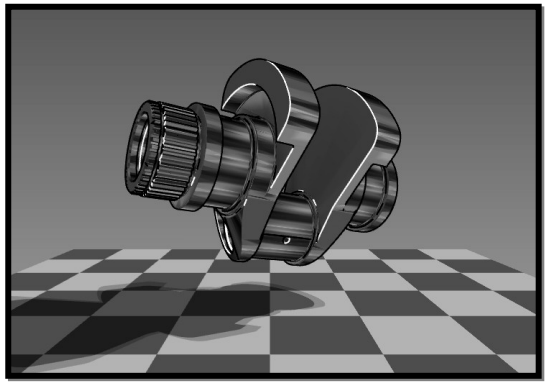
Previous Work

NPR

Real-Time ~~Hatching~~

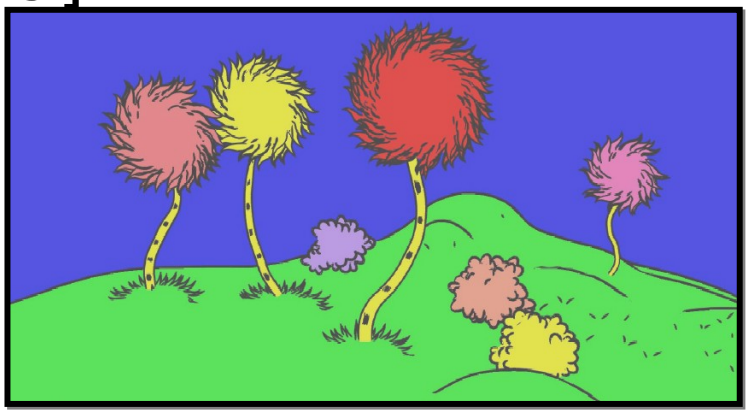
- Technical Illustration

  [Gooch *et al.* ’99]



- Graftals

  [Kowalski *et al.*

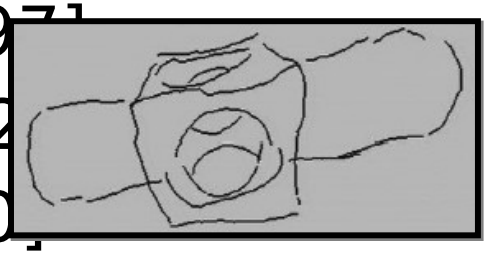


- Silhouette rendering

  [Markosian *et al.* ’97]

  [Hertzmann *et al.* 2

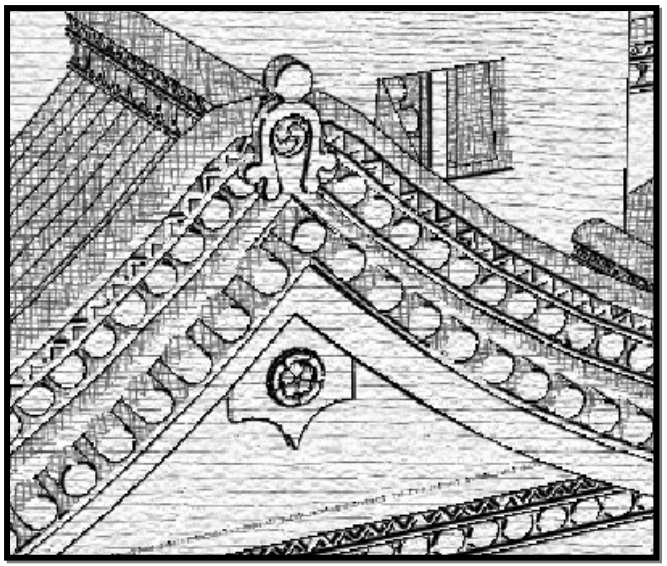
  [Sander *et al.* 2000]



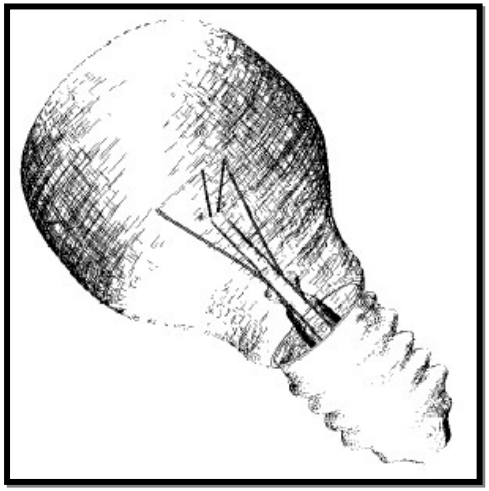
Previous Work

Real-Time Hatching

- Screen-space “filter” [Lake *et al.* 2000]

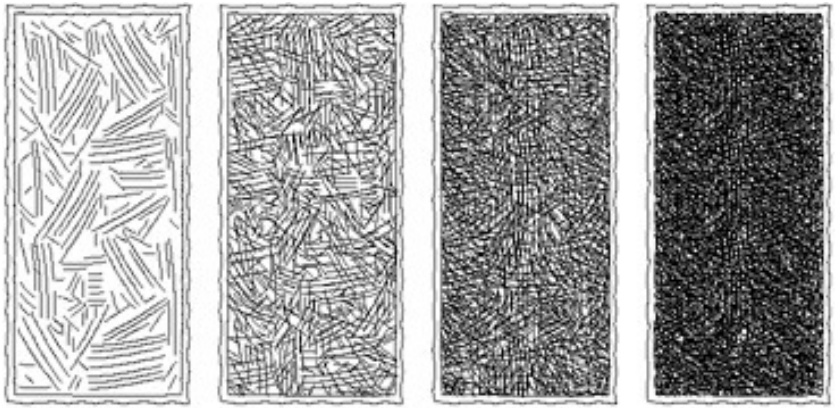


- Fixed density strokes [Elber ’99]

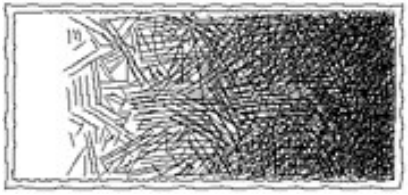


Previous Work – Stroke Collections

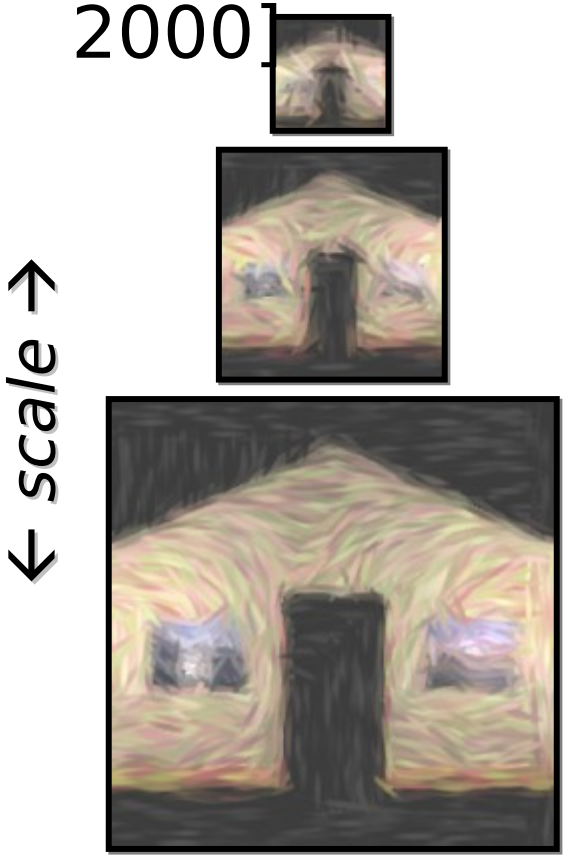
Prioritized Stroke Textures
[Salisbury *et al.* ’94]
[Winkenbach *et al.* ’94]



← *tone* →



Art Maps
[Klein *et al.* 2000]



← *scale* →

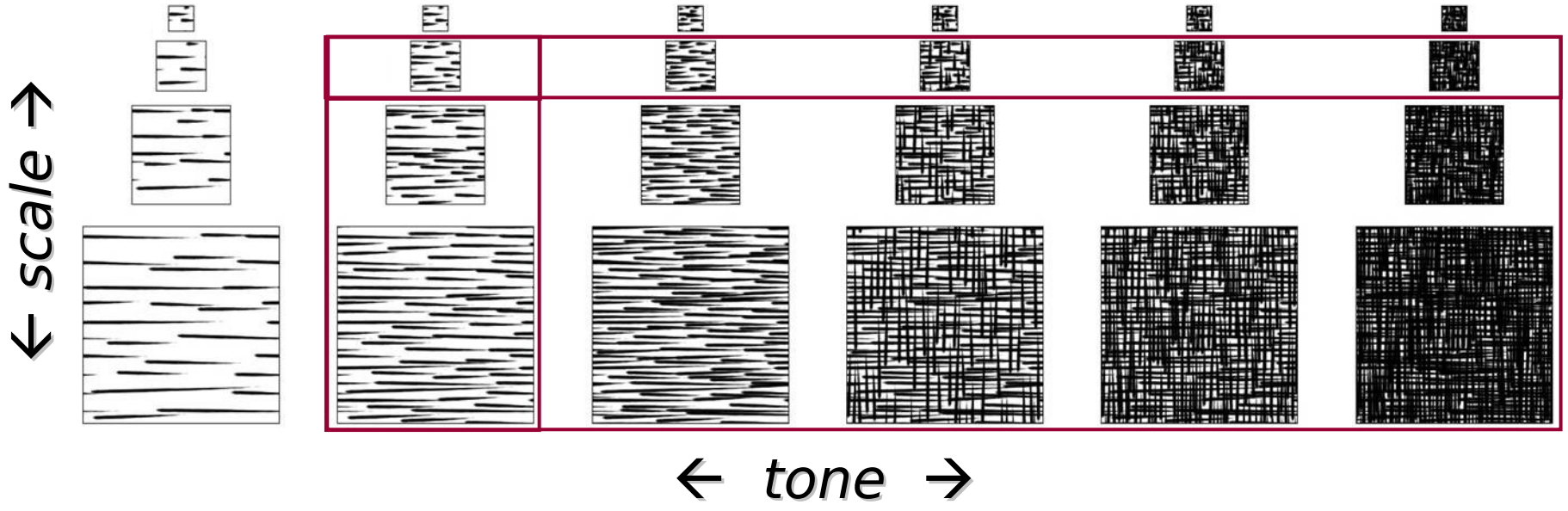
Tonal Art Maps

Collection of stroke images

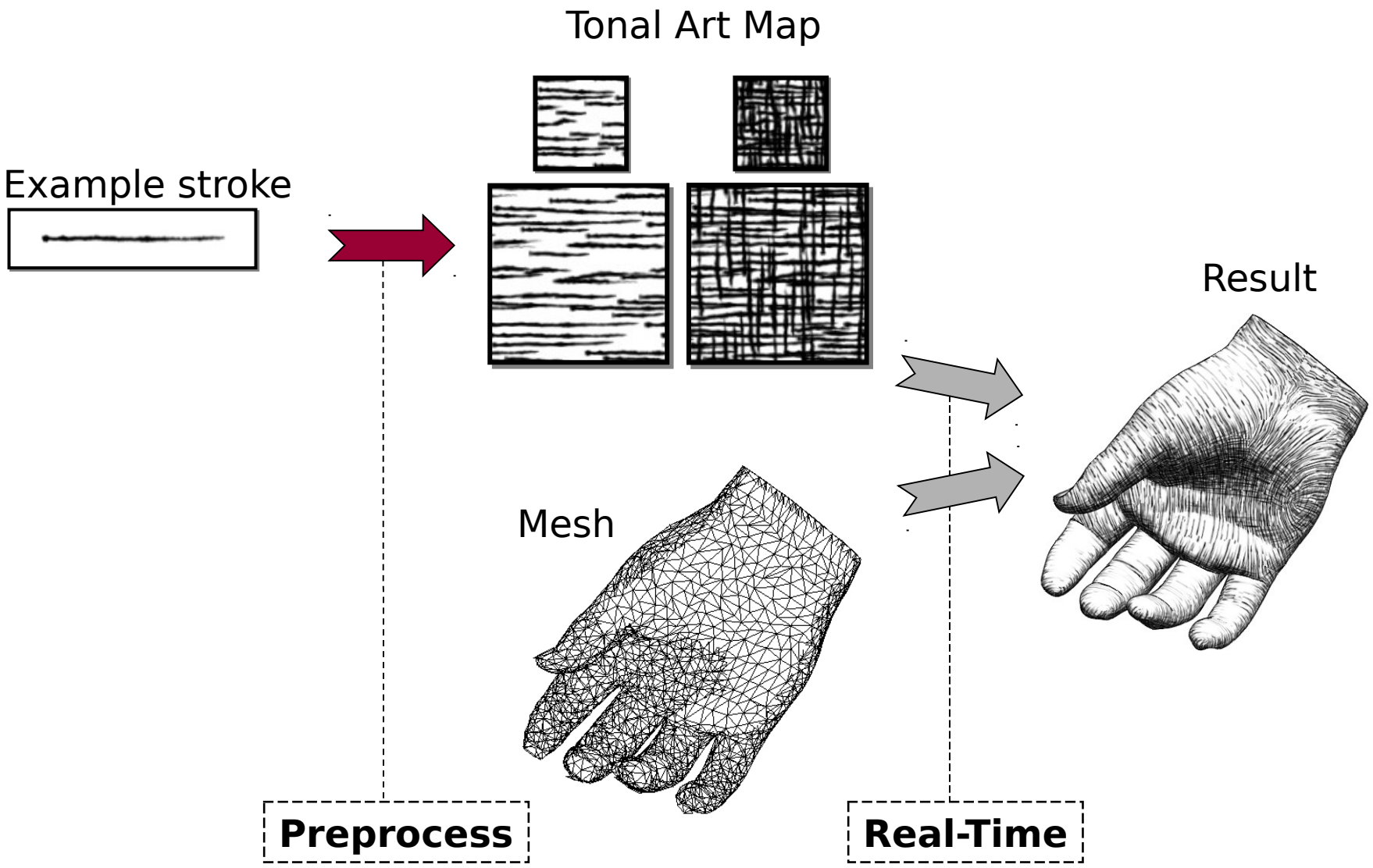
Will blend → design with high coherence

Stroke nesting property

demo



Approach

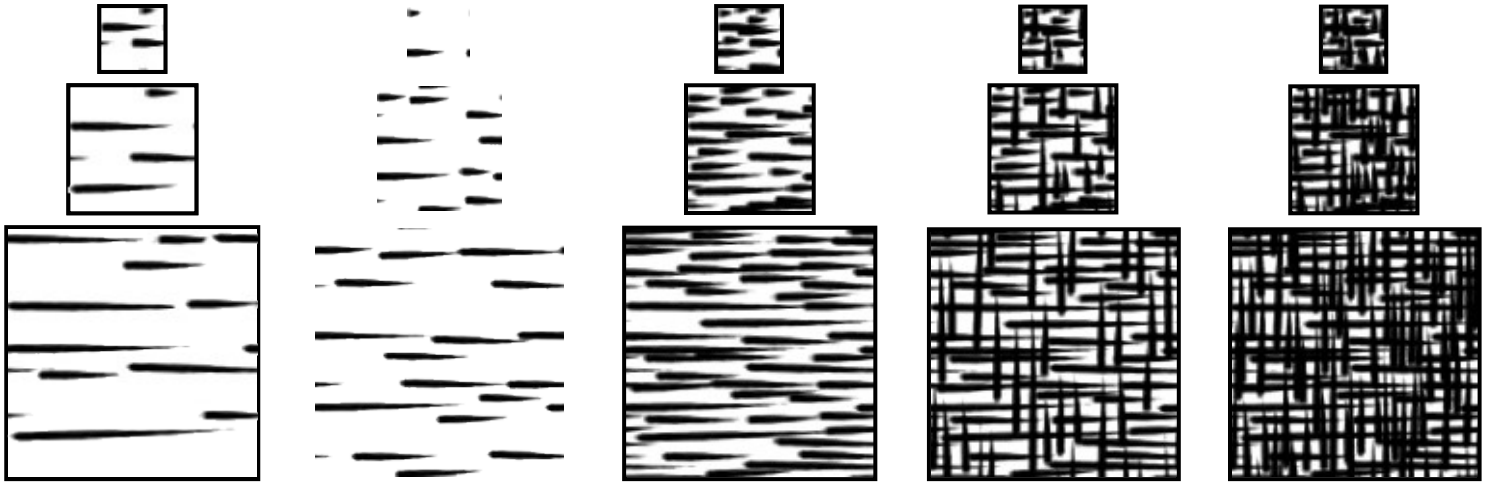

Tonal Art Map
Example stroke
Result
Mesh
Preprocess
Real-Time

Generating Tonal Art Maps

Draw or import bitmap for one stroke

Automatically fill TAM with strokes

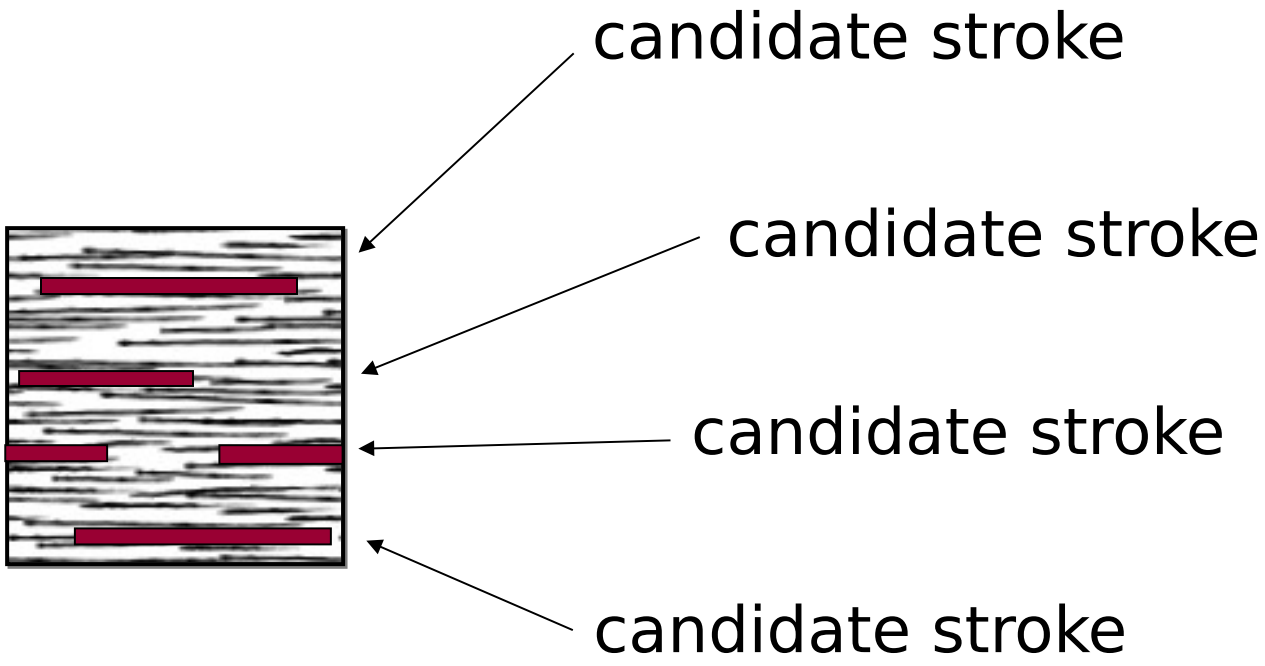
- When placing stroke in an image, add it to all finer & darker images
- Fill table column by column, coarse to fine
- Space strokes evenly



Even Spacing of Strokes

Choose best stroke from large candidate pool

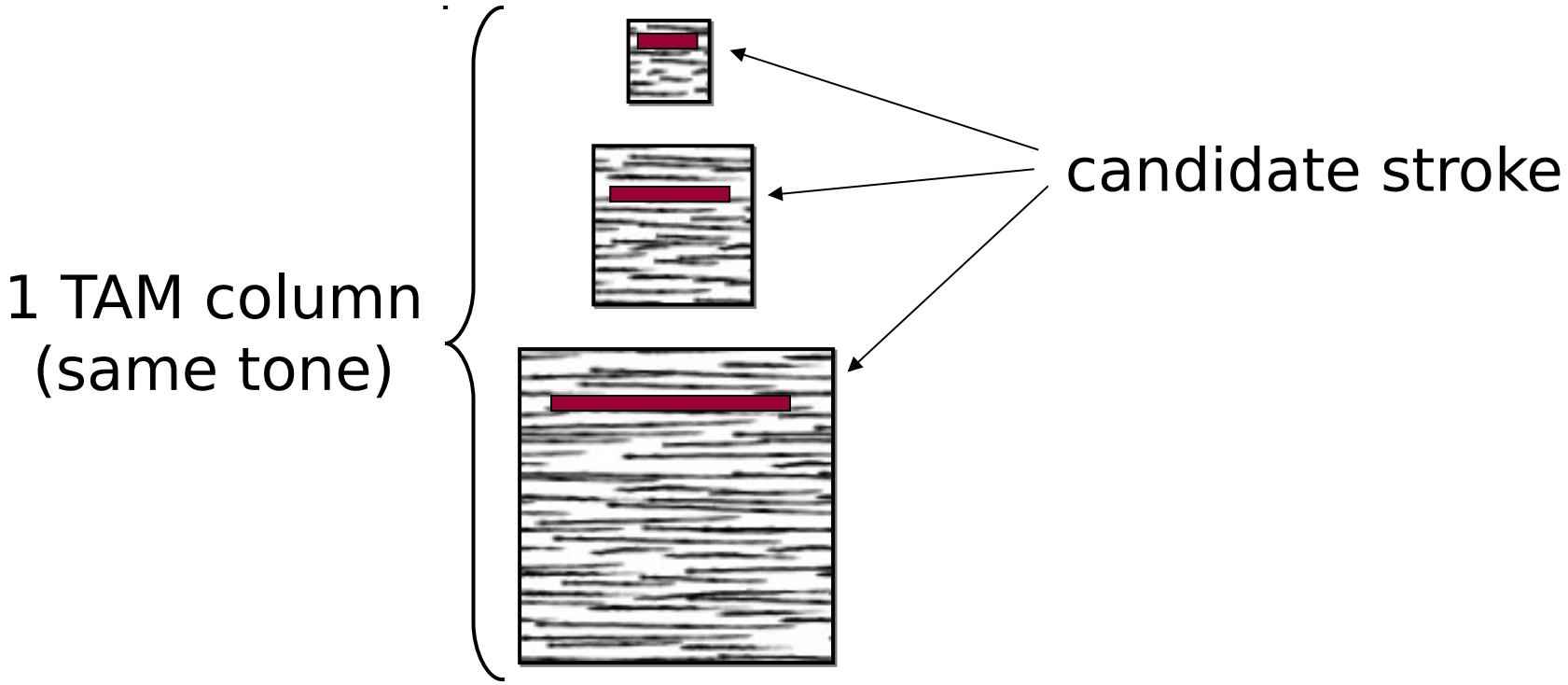
Fitness = uniformity & progress towards tone



Even Spacing of Strokes

Choose best stroke from large candidate pool

Fitness = uniformity & progress towards tone

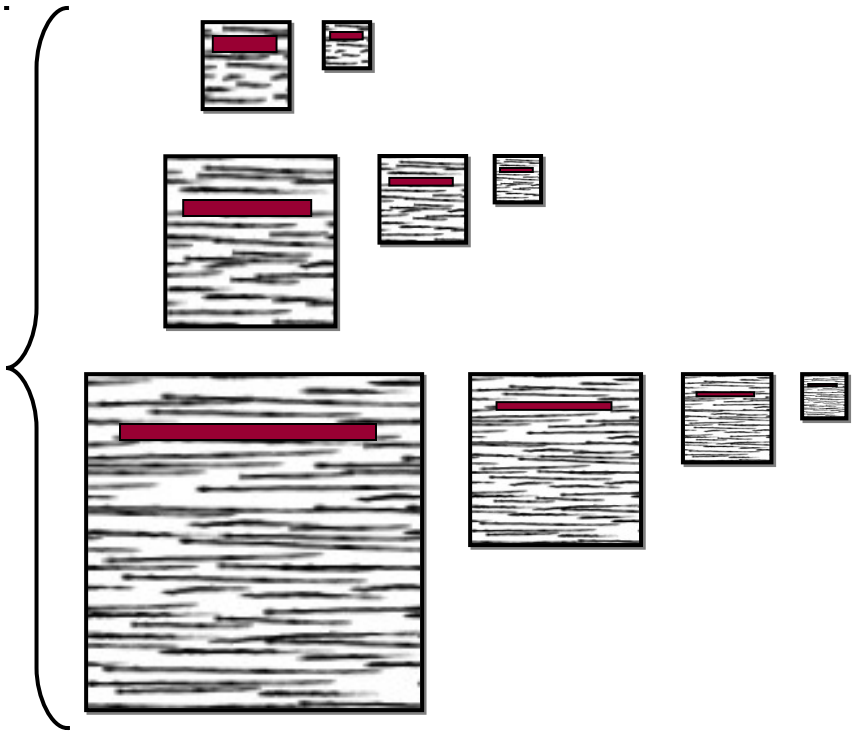


Even Spacing of Strokes

Choose best stroke from large candidate pool

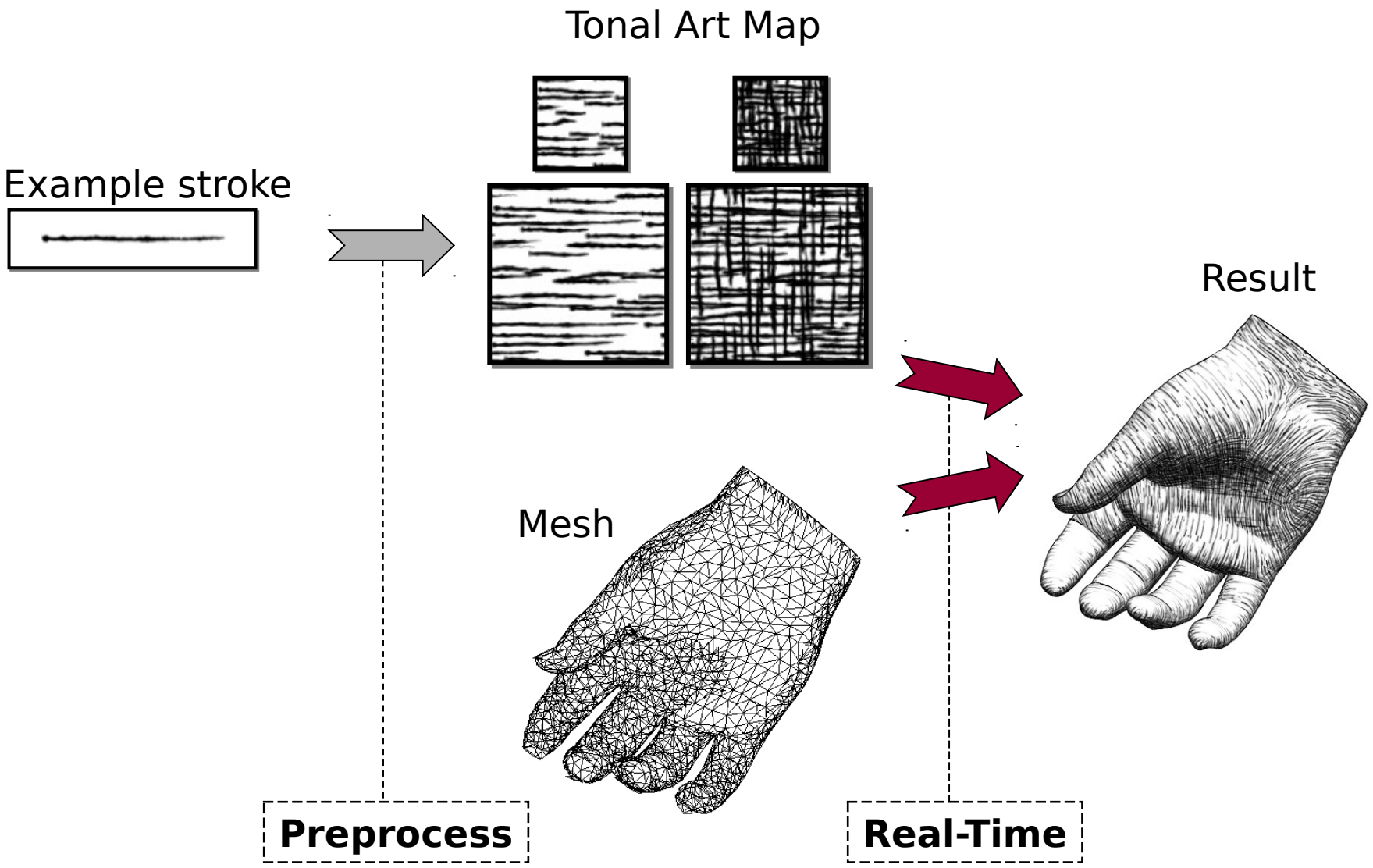
Fitness = uniformity & progress towards tone

1 TAM column
(same tone)



Keep Gaussian pyramid for all TAM images

Approach

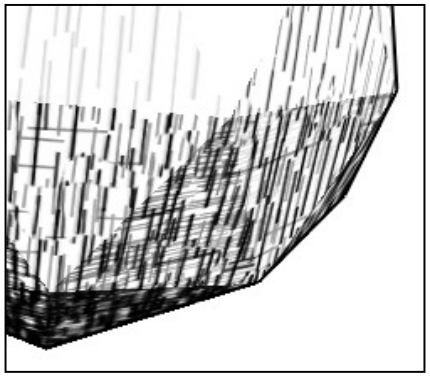

Tonal Art Map
Example stroke
Result
Mesh
Preprocess
Real-Time

Continuity

Stroke size continuity → mipmapping

Tone continuity → blend multiple textures

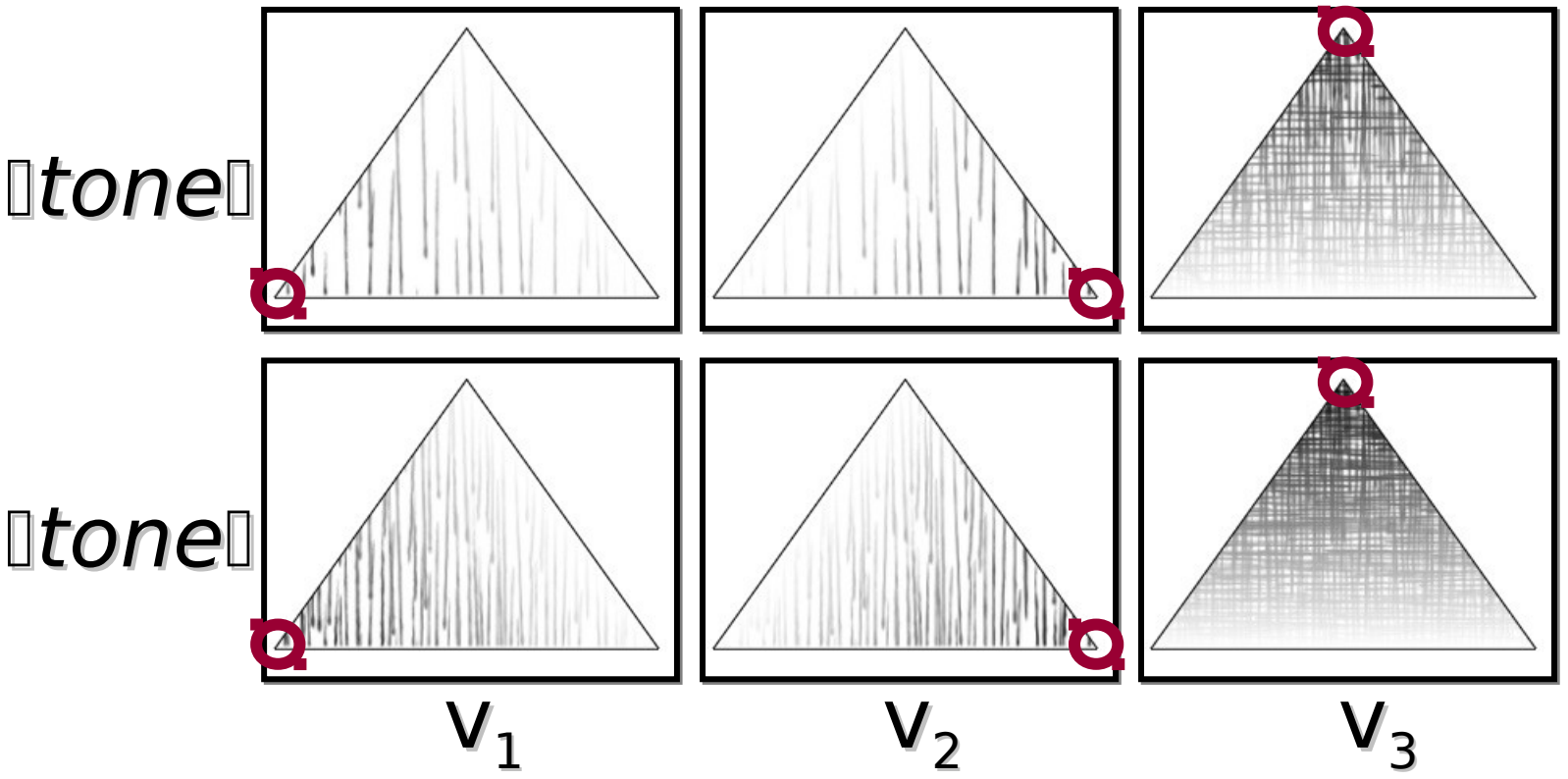
- Spatial continuity: same contribution for a texture on both sides of an edge



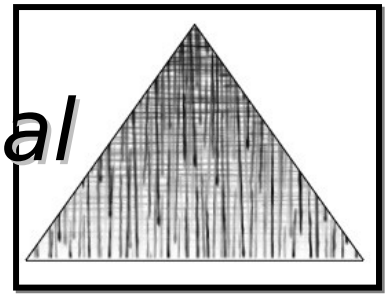
spatial discontinuity

- Temporal continuity: no “popping” demo

Texture Blending



6-way blend → final



Texture Blending

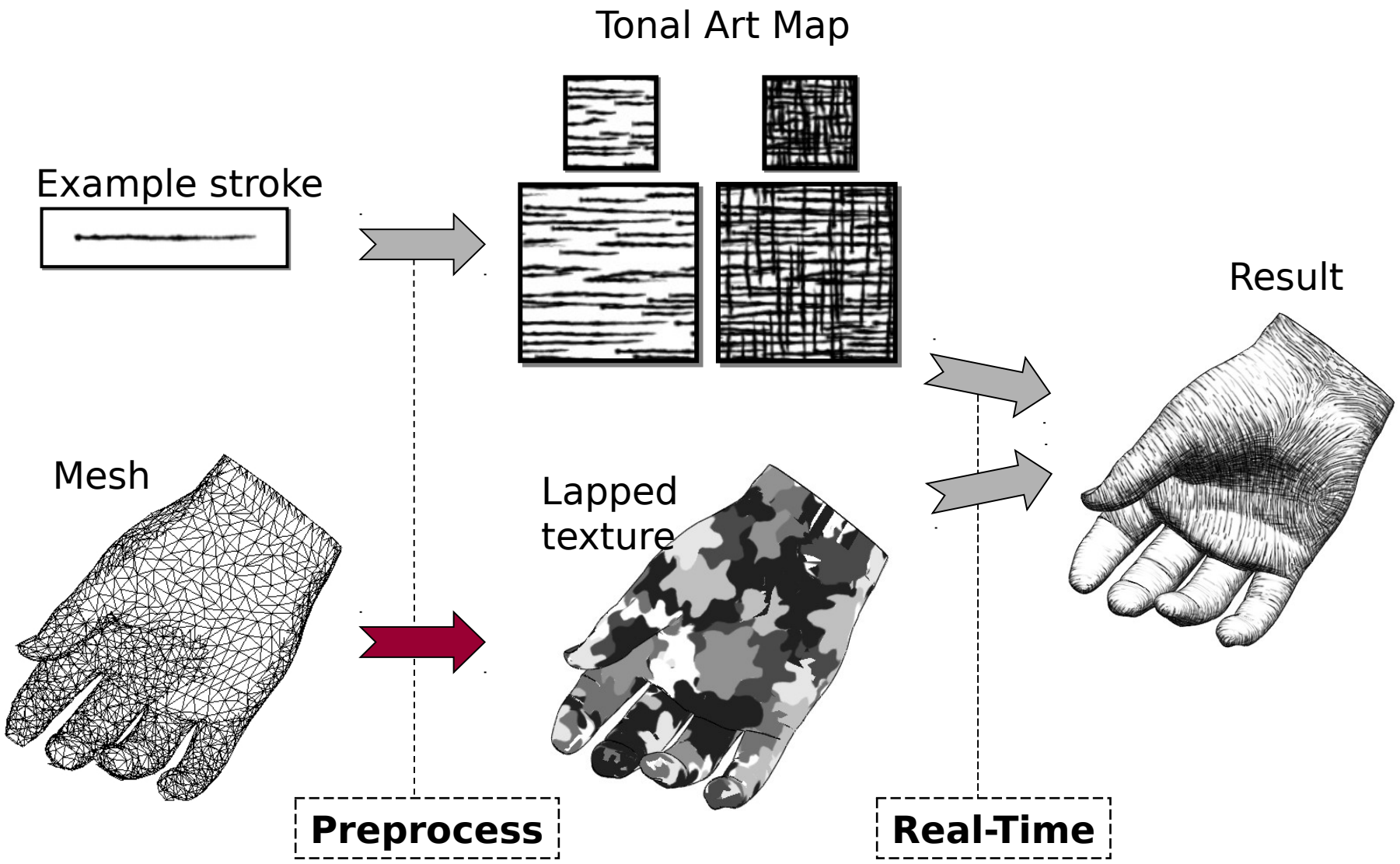
Pack grayscale tones in R,G,B channels
→ 6 tones in 2 textures

Use multitexture engine
→ single-pass 6-way blend

Vertex programs compute blend weights
→ static vertex data

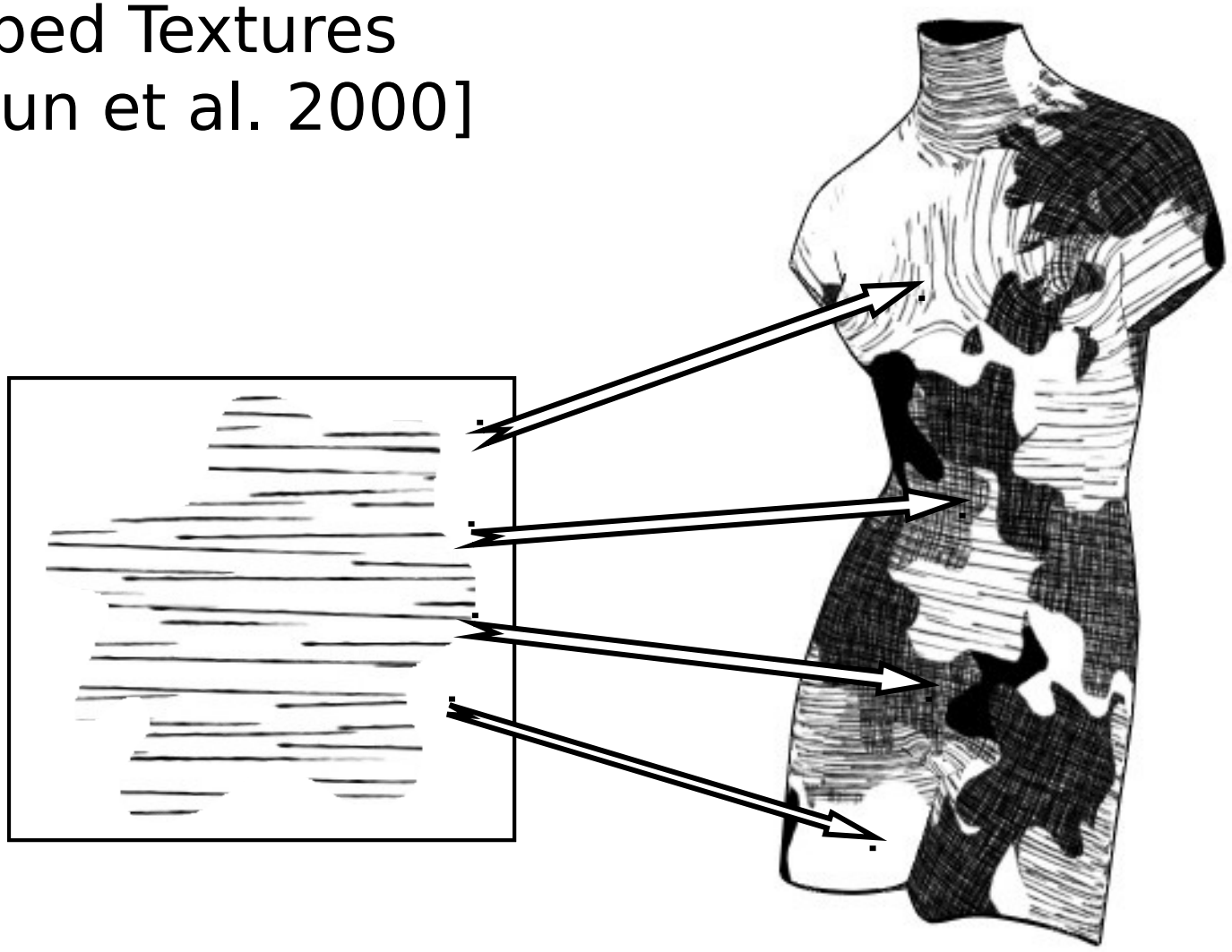
```
 !!VP1.0 #Vertex Program for Real-Time Hatching.
//output vertex homogeneous coordinates
DP4   R2.x, c[0], v[OPOS];
DP4   R2.y, c[1], v[OPOS];
DP4   R2.z, c[2], v[OPOS];
DP4   R2.w, c[3], v[OPOS];
MOV   o[HPOS], R2;
//stroke texture coordinates, transformed
DP3   o[TEX0].x, c[4], v[TEX0];
DP3   o[TEX0].y, c[5], v[TEX0];
DP3   o[TEX1].x, c[4], v[TEX0];
DP3   o[TEX1].y, c[5], v[TEX0];
// splotch mask coordinates
MOV   o[TEX2], v[TEX0];
//get the Gouraud shade
DP3   R1, c[8], v[NRML];
//apply clamp-linear tone transfer function
MUL   R1, R1, c[9].x;
ADD   R1, R1, c[9].y;
MAX   R1, R1, c[9].z;
MIN   R1, R1, c[9].w;
//now look up the weights for the TAMs blending
EXP   R2.y, R1.x; //frac(tone)
ARL   A0.x, R1.x;
MOV   R3, c[A0.x + 10];
MAD   R3, -R2.y, R3, R3;
MAD   o[COL1], R2.y, c[A0.x + 11], R3;
MOV   R4, c[A0.x + 20];
MAD   R4, -R2.y, R4, R4;
MAD   o[COL0], R2.y, c[A0.x + 21], R4;
END
```

Approach


Tonal Art Map
Example stroke
Result
Mesh
Lapped
texture
Preprocess
Real-Time

Texturing Arbitrary Surfaces

Lapped Textures
[Praun et al. 2000]

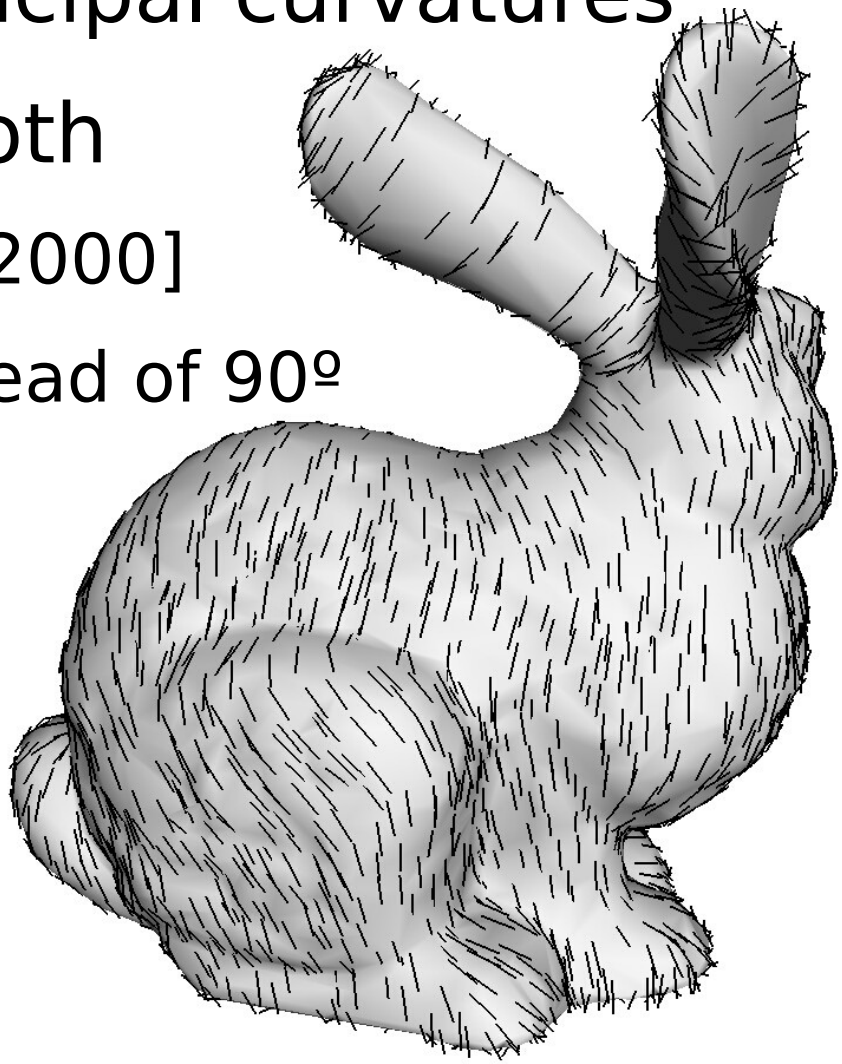


Direction Field

Based on surface principal curvatures

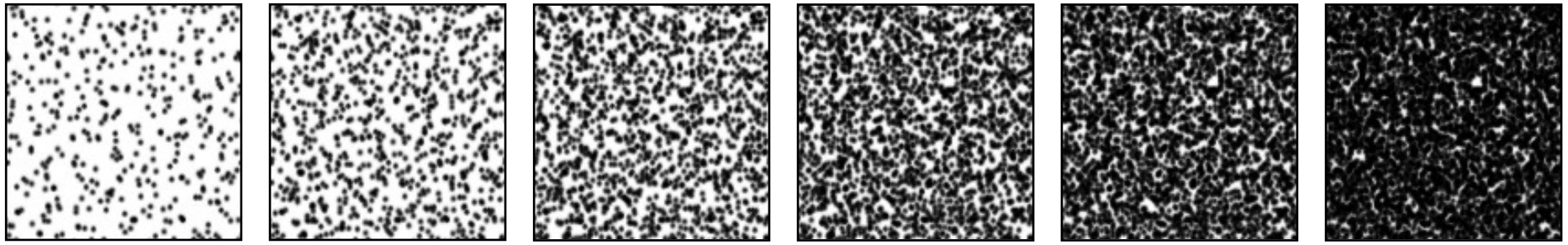
Optimized to be smooth

- [Hertzmann & Zorin 2000]
- Symmetry: 180º instead of 90º
- Sample on faces



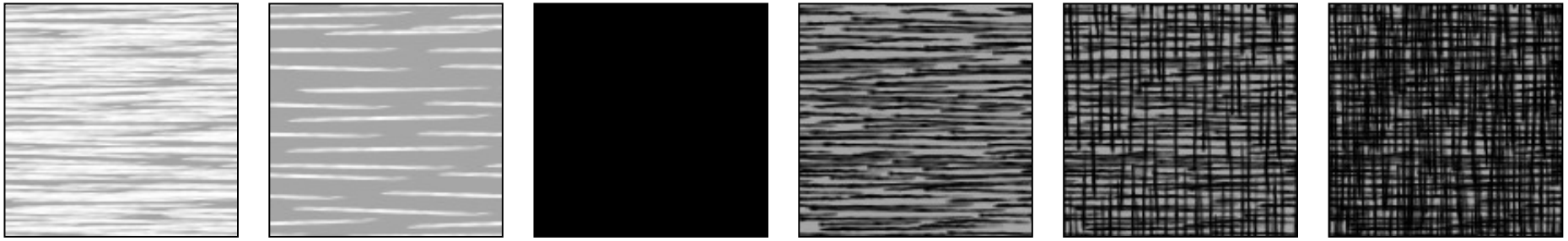
Demo

Demo



Gargoyle

Demo



← *chalk* *gray* *charcoal*
→

Venus

Summary

Real-time hatching for NPR

Strokes rendered as textures

High coherence TAMs prevent blend artifacts

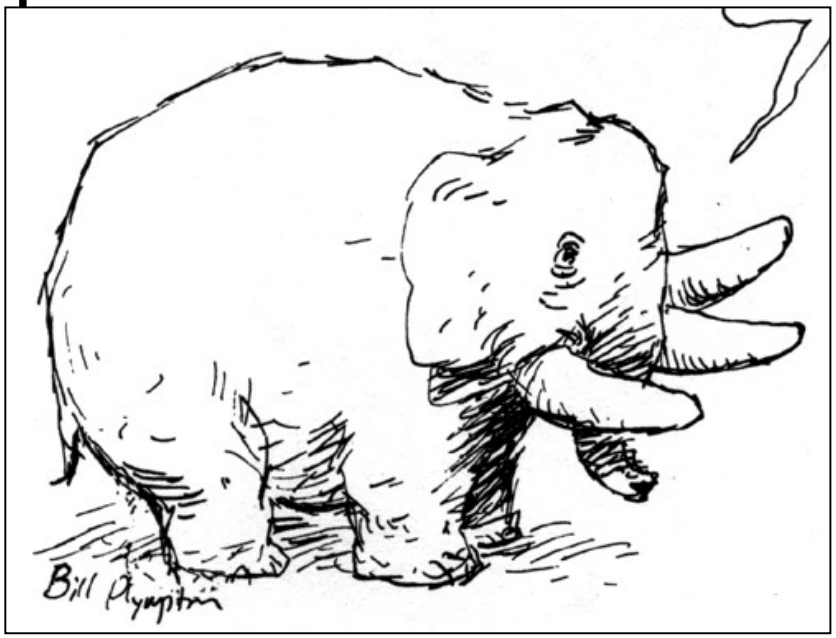
6-way blend very fast on modern graphics

Future Work

More general TAMs

View-dependent stroke direction

Automatic indication



Bill Plympton

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International Symposium on
Non-Photorealistic Animation and Rendering

- Annecy, France
- Submissions: November 12, 2001
- Conference:June 3-5, 2002

http://npar2002.cs.princeton.edu